

USE OF AGROWASTE IN CONCRETE CONSTRUCTION

DEVINDER SINGH¹ & JASPAL SINGH²

¹Student, Department of Civil Engineering, Punjab Agricultural University, Ludhiana, Punjab, India

²Professor, Department of Civil Engineering, Punjab Agricultural University, Ludhiana, Punjab, India

ABSTRACT

The use of agro-waste in concrete manufacture gives an appropriate solution to many environment concerns and burdens associated with waste management. A large amount of agricultural waste such as bagasse, rice husk, wheat straw, coconut shell etc. is produced in most of developing as well as developed countries. The large part of these wastes is being used as fuel for power generation which results into the ash. However, this ash has been considered being a waste material, which causes the problems of disposal. Furthermore, if this reutilization of waste as fuel is occurred under controlled temperature and atmosphere, the ash will be a rapidly reactive (due to high amorphous silica content) for pozzolanic activity during cement hydration. Therefore, agro-waste like ground shell ash, rice husk ash, sugarcane bagasse ash etc. can be used as cement replacement while coconut shell, oil palm shell etc. used as aggregates replacement in concrete. This paper presents an overview of the published data on the use of rice husk ash, sugarcane bagasse ash, groundnut ash and coconut shells in concrete. Effect of these wastes on the properties of concrete such as workability and compressive are presented.

KEYWORDS: Agrowaste, Coconut Shell, Concrete, Compressive Strength, Ground Nut Ash, Rice Husk Ash, Sugarcane Bagasse Ash, Workability

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INTRODUCTION

Agrowaste is the waste produced from various agricultural goods. Bagasse from Sugarcane, Wheat Husk and Wheat Straw from Wheat, Groundnut Shell from Groundnut, Rice Husk from Paddy, and Coconut Shell from Coconut etc. are the wastes of agriculture. Most of the developing countries produce near about 400 million tons of agricultural waste annually. Nowadays, some of the wastes such as rice husk, bagasse, shell of ground nuts etc. are partly used as a fuel for power generation. This utilization results into ash which causes the problem of disposal. Moreover, this ash is produced under controlled temperature conditions and contains high levels of SiO_2 and AL_2O_3 which enabling its use as pozzolans in concrete. Apart from it, some wastes such as coconut shell, oil palm shell etc. having excellent physical properties and can be used as coarse aggregates in concrete. In addition, the utilization of these waste not only solve the problem of environmental pollution but can also improve the strength and durability properties of concrete. So, there is a great need to utilize these wastes in this manner which helps to maintain the clean environment.

Concrete is a manmade composite similar in properties to some natural lime stone rocks. Cement, fine aggregates (sand), coarse aggregates (gravels) and water are the main ingredients of this artificial material. It can produce required strength due to the hydration (chemical process of water and cement) of cement paste. The use of concrete is increasing day by day due to development in infrastructure in both developed and developing

countries. This higher demand of concrete is further increasing the consumption of their ingredients which has so many negative impacts on environment. These negative impacts include the environmental pollution and its degradation. Cement industry plays important role in environmental pollution because for production of cement, clay and limestone mixed with other materials needs to be heated at higher temperature to obtain clinker. In this production CO₂ emission come from both industrial process and fuel combustion which is the largest driver of global warming as stated by Intergovernmental panel on climate change (IPCC). Another negative consequence of higher demand of concrete is the extensive extraction of aggregates from natural resources which results into environmental degradation, ecological imbalance and create a question about the preservation of natural resources of aggregates. Therefore, it becomes essential and more significant to find out the substitutes for cement as well as natural aggregates.

Until now, industrial wastes such as fly ash, blast furnace slag etc. has been used in concrete, but the use of agrowaste is very rare. So, the aim of this review paper is to spread awareness of using agrowaste in concrete.

RICE HUSK ASH (RHA)

Rice Husk, a by-product of rice processing, is produced in large quantities globally every year. This husk is used as fuel in the rice mills to generate steam, which is converted into ash during the firing process, is known as rice husk ash (RHA). RHA can be used as a partial replacement for cement in concrete because of its very high silica content.

Properties of RHA

RHA is mainly consists of oxide of silicon, iron, and aluminum with small amount of oxide of calcium and magnesium. Its chemical composition depends on the burning temperature and the heating duration of rice husk. Due to the high content of silicon, aluminum and iron RHA have good pozzolanic properties. The chemical and physical properties of RHA are given in Table 1 and Table 2 respectively.

Table 1: Chemical Composition of RHA

| Chemical Composition | Kartini (2011) | Khassaf et al. (2014) | Singh and Kumar (2014) | Ramezaniapour et al (2009) | Habeeb and Mahmud (2010) |
|--------------------------------|----------------|-----------------------|------------------------|----------------------------|--------------------------|
| SiO ₂ | 96.7 | 90.18 | 93.80 | 90.21 | 88.32 |
| Al ₂ O ₃ | 1.01 | 0.51 | 0.74 | 0.06 | 0.46 |
| Fe ₂ O ₃ | 0.05 | 0.17 | 0.30 | 0.27 | 0.67 |
| MgO | 0.19 | 0.70 | 0.32 | 0.49 | 0.44 |
| CaO | 0.49 | 2.64 | 0.89 | 0.85 | 0.67 |
| LOI | 4.81 | 2.30 | 4.00 | 5.48 | 5.81 |

Table 2: Physical Properties of RHA

| Physical Properties | Rao et al. (2014) | Tashima et al. (2008) | Ramezaniapour et al (2009) |
|---------------------|-------------------|-----------------------|----------------------------|
| Particle size | 25 micron | 12.3 micron | - |
| Specific gravity | 2.30 | 2.16 | 2.15 |

Workability and Strength Characteristics of RHA Concrete

Habeeb and Mahmud (2010) studied the properties of RHA and its use in concrete. They investigated the effect of RHA replacement on compressive strength and workability of concrete mixtures. They replaced cement with RHA up to 20% by weight. They found that the slump of RHA concrete was lower than the reference concrete. From their study, they also concluded that the compressive strength of blended concrete was increased as the content of RHA increased as shown in Figure 1. The optimum value of replacement was 10% at which strength increased significantly as compared to reference mixture.

Khassaf et al (2014) found that the workability decreases with the increase of the replacement level of the cement with the RHA as shown in Figure 2. The slump reduced from 70 to 15 when the replacement level increased from 0% to 30%. They also observed that the compressive strength decreased with the increase in the RHA content at short term ages (7 and 28 days) and increased with the increase in the RHA content at long term ages (56 and 90 days). They also found that the compressive strength of concrete with up to 20% RHA replacement attained values more than that of control or reference concrete. The compressive strength behavior of concrete at different curing ages is shown in Figure 3.

Kartini (2011) investigated the effect of RHA on compressive strength of different grades of concrete at different curing ages. He observed that compressive strengths were increased at 28, 60, 90 and 120 curing ages by the replacement of cement with RHA. He also found that the optimum replacement of OPC with RHA for Grade 30 and Grade 40 is 30%, while for Grade 50 is 20%. In case of workability, he concluded that workability decreases with the increase of the replacement level of the RHA with the cement, due to its absorptive character of cellular particles and of high fineness.

Obilade (2014) studied the effect of RHA as partial replacement of cement in concrete. He was replaced cement with RHA by weight at 0%, 5%, 10%, 15%, 20% and 25% replacement levels and examined the workability and compressive strength characteristics of concrete. He found that compacting factors values were decreased as RHA content increased as

Habeeb and Mahmud (2010)

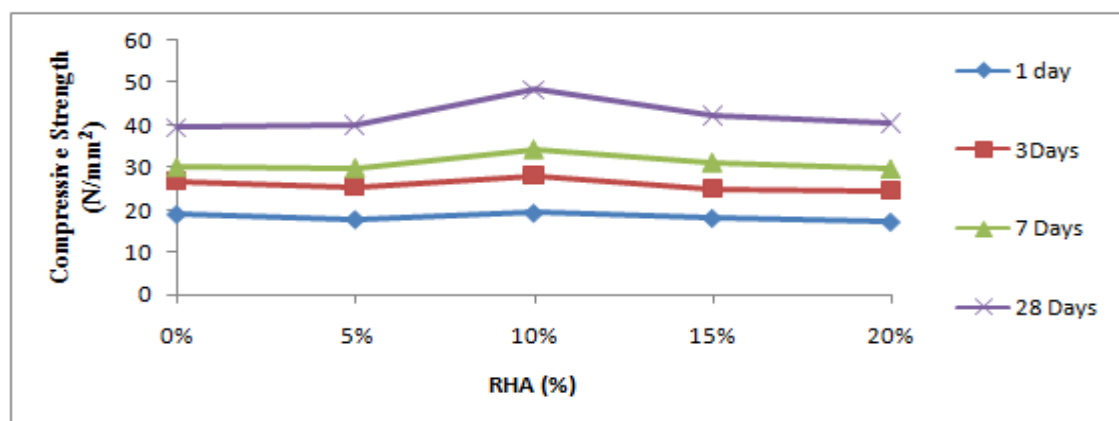


Figure 1: Compressive Strength Results of RHA Concrete

Khassaf et al (2014)

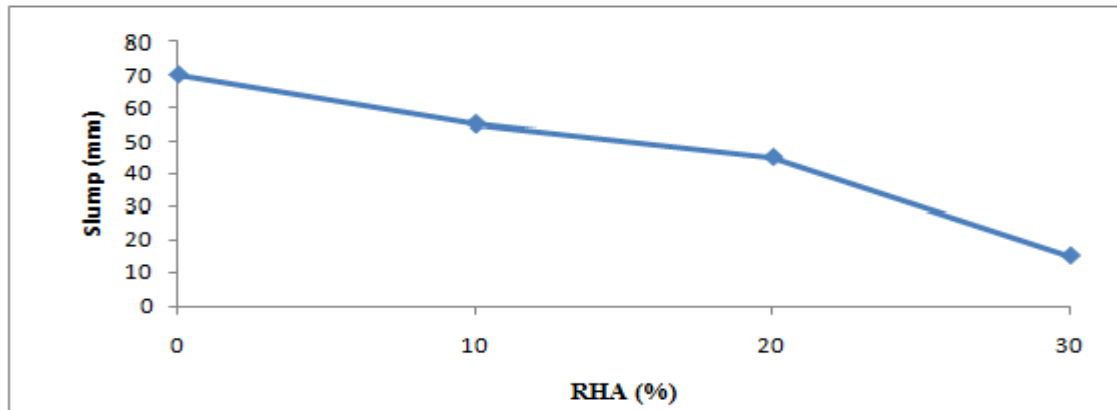


Figure 2: Slump Value of RHA Concrete Mixture

Khassaf et al (2014)

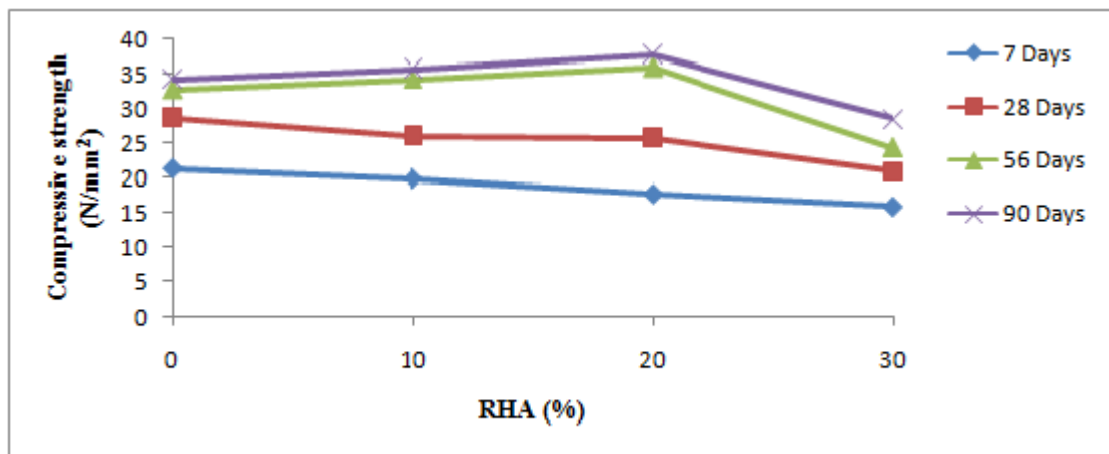


Figure 3: Compressive Strength of RHA Concretes at different Curing Ages

Illustrated by Figure 4. The values were decreased from 0.91 to 0.88 when cement was replaced up to 25% with RHA. He also observed that the compressive strength of concrete reduced as the percentage RHA increased but the compressive strengths increased as the number of days of curing increased for each percentage RHA replacement. The results of compressive strength at different replacement levels of RHA are shown in Figure 5.

Rao et al (2014) demonstrated that at a fixed W/C ratio the compressive strength decreased with the increase in the RHA content at the initial ages (3 and 7 days) however as the age advances there was a significantly increased in the strength of concrete up to 7.5 % replacement level of RHA with the OPC.

Singh and Kumar (2014) examined the effect of RHA as cement replacement at levels of 0%, 5%, 10% and 15% by mass at fixed water cement ratio of .50. They demonstrated that the compressive strength increased at 5 % replacement level of RHA, and decreased with further increase in the RHA content at 7 and 14 days curing ages.

Obilade (2014)

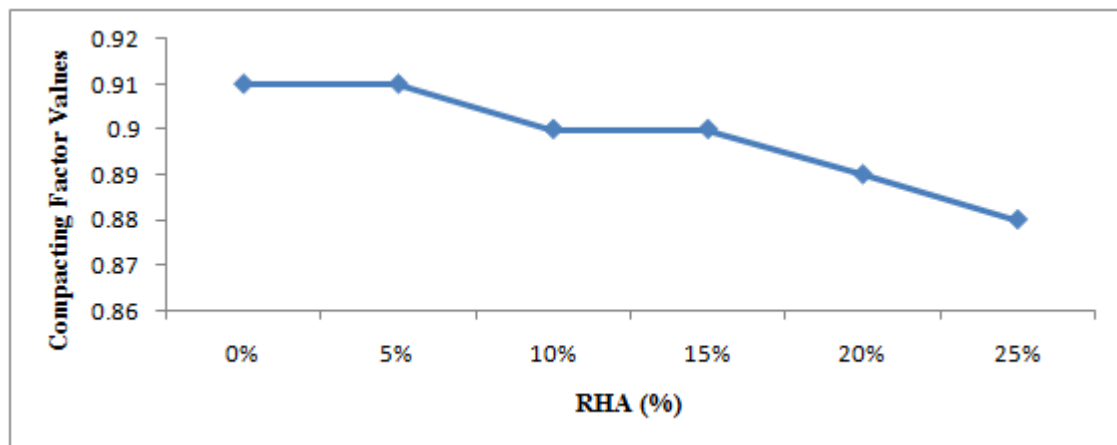


Figure 4: Compacting Factor Values of different RHA Concrete Mixtures

Obilade (2014)

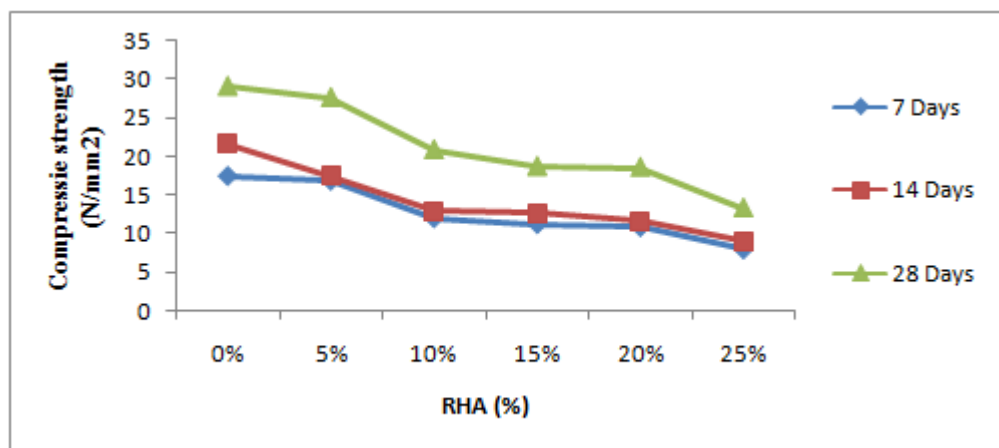


Figure 5: Compressive Strength of RHA Concrete at different Replacement Level with Cement

Tashima et al (2007) found that the addition of RHA causes an increment in the compressive strength due to the pozzolanic reactivity of RHA with the calcium hydroxide which is generated during the cement hydration. All the replacement level of RHA increased the compressive strength. For a 5% of RHA, 25% of increment is verified when compared with control mixture.

SUGARCANE BAGASSE ASH (SCBA)

Sugarcane is one of the major crops grown in over 110 countries. The fibrous matter that remains after crushing and juice extraction of sugarcane is known as bagasse. Nowadays, this bagasse is to reutilize as a biomass fuel in boilers for vapor and power generation in sugar mills. When this bagasse is burned under controlled temperature, it results into ash.

Properties of SCBA

The chemical composition of SCBA dominates by silicon dioxide. In addition, small amount of calcium, iron, aluminum, and magnesium are also present which make it pozzolanic material by satisfying the chemically requirement of

a good pozzolan as specified by IS code. The chemical composition and physical properties of SCBA is given in Table 3 and Table 4 respectively.

Table 3: Chemical Composition of SCBA

| Chemical Composition | Ganesan et al. (2007) | Cordeiro et al. (2008) | Janjaturaphan and Wansom (2010) | Otouze et al (2012) | Lavanya et al. (2012) |
|--------------------------------|-----------------------|------------------------|---------------------------------|---------------------|-----------------------|
| SiO ₂ | 64.15 | 78.34 | 75.27 | 60.98 | 67.81 |
| Al ₂ O ₃ | 9.05 | 8.55 | 5.38 | 7.39 | 19.39 |
| Fe ₂ O ₃ | 5.52 | 3.61 | 2.54 | 6.07 | 3.85 |
| MgO | 2.85 | - | 1.15 | 2.51 | 1.11 |
| CaO | 8.14 | 2.15 | 3.74 | 12.66 | 4.03 |
| LOI | 4.90 | 0.42 | 7.18 | 4.80 | 1.9 |

Table 4: Physical Properties of SCBA

| Physical Properties | Chusilp et al (2009) | Rukzon and Chindaprasirt (2012) | Ganesan et al (2007) |
|---------------------------------|----------------------|---------------------------------|----------------------|
| Particle size | - | 16.4 micron | 5.40 micron |
| Retained on 45 micron sieve (%) | 2.8 | 2.5 | - |
| Specific gravity | 2.20 | 2.24 | 1.85 |

Workability and Strength Characteristics of SCBA Concrete

Chusilp et al (2009) investigated the physical properties of SCBA concrete such as compressive strength, water permeability, and heat evolution of SCBA. They replaced cement with SCBA at different replacement levels (10, 20 and 30%) with constant w/c ratio (0.50). They concluded that, at the age of 28 days, the concrete samples containing 10–30% SCBA by weight of binder had greater compressive strengths than the control concrete. Concrete containing 20% SCBA had the highest compressive strength at 113% of the control concrete. The effect of different curing ages and percentage replacement of SCBA on compressive strength is illustrated Figure 6. They were also used super plasticizer to control the slump of fresh concrete. According to them, SCBA can be used as a pozzolanic material in concrete with an acceptable strength, lower heat evolution, and reduced water permeability with respect to the control concrete.

Cordeiro et al (2010) described the characterization of SCBA produced by controlled burning and ultrafine grinding. Initially, they were examined optimum burning conditions of the bagasse which helped them to find maximum pozzolanic activity. The results demonstrated that an amorphous SCBA with high specific surface area and reduced loss on ignition can be produced with burning at 600 °C in muffle oven. After observing optimum burning they investigated the grinding procedure of SCBA. They concluded that the grinding in vibratory mill for 120 min enabled the production of an ash with pozzolanic activity index of 100% which can be replaced cement up to 20%.

Fairbairn et al (2010) studied the effect of SCBA as partial replacement of cement in concrete. SCBA was replaced with cement at the ratio of 0%, 10%, 15% and 20 %. All specimens were cured for 7, 28, 90 and 180 days. Based on their test results, they concluded that an optimum of 10% SCBA blend with OPC could be used for reinforced concrete.

Ganesan et al (2007) studied the effect of SCBA as supplementary cementitious material on the properties of concrete. Seven different proportions of concrete mixes (bagasse ash ranging from 5% to 30% by weight of cement) including the control mix were prepared with a water binder ratio of 0.53. Compressive strength of bagasse ash blended

cement concrete cubes was determined after 7, 14, 28 and 90 days curing. This study concluded that up to 20% of cement can be replaced with SCBA without any adverse effect on the strength of concrete while 10% of cement can be replaced to achieve desirable workability of fresh concrete.

Lavanya et al (2012) studied the effect of SCBA as partial replacement of cement in concrete. SCBA was partially replaced with cement at the ratio of 0%, 5%, 10%, 15% and 30% for three different water cement ratios i.e. 0.35, 0.40 and 0.45. For each water cement ratio and replacements 3 cubes were casted and its average compressive strength is tabulated for 7, 14 and 28 days. According to the results obtained, it can be concluded that: SCBA can increase the overall strength of the concrete when used up to a 15% cement replacement level with w/c ratio of 0.35.

Otuozue et al (2012) investigated the effect of sugarcane SCBA as partial replacement of cement in concrete. All cube specimens were cured for 7, 14, 21, and 28 days for 0, 5, 10, 15, 20, 25, 30, 35 and 40% SCBA blended with OPC. The compressive strength of the specimens was determined in accordance to BS 1881 (1983). Based on the various tests conducted, it can be succinctly concluded that SCBA is a good pozzolana for concrete cementation and partial blends of it with cement could give good strength development and other engineering properties in concrete. An optimum of 10% SCBA blend with cement could be used for reinforced concrete. Higher blends of 15% and up to 35% of SCBA with cement are acceptable for plane or mass concrete.

Rukzon and Chindaprasirt (2012) studied the effect of SCBA as partial replacement of cement in high strength concrete. In this study cement was partially replaced with 10%, 20% and 30% of SCBA. For all mixes, 100 mm diameters and 200 mm height of cylindrical specimens were cast for compressive strength testing. They were tested at the ages of 7, 28 and 90 days. This study concluded that coal SCBA improves the strength of concrete. The concrete containing up to 30% of SCBA exhibited better compressive strength than conventional concrete.

Srinivasan and Sathiya (2010) studied the effect of SCBA as partial replacement of cement in concrete. SCBA was partial replaced with cement at the ratio of 0%, 5%, 10%, 15% and 25% by weight. This study examined the workability, compressive strength, split tensile strength, flexural strength, young's modulus and density of concrete. The results explained that the SCBA in blended concrete had significantly higher workability, compressive strength, tensile strength, and flexural strength compare to that of the concrete without SCBA. It is found that the cement could be advantageously replaced with SCBA up to maximum limit of 10%. The compressive strength result are shown in Figure 7.

Chusilp et al (2009)

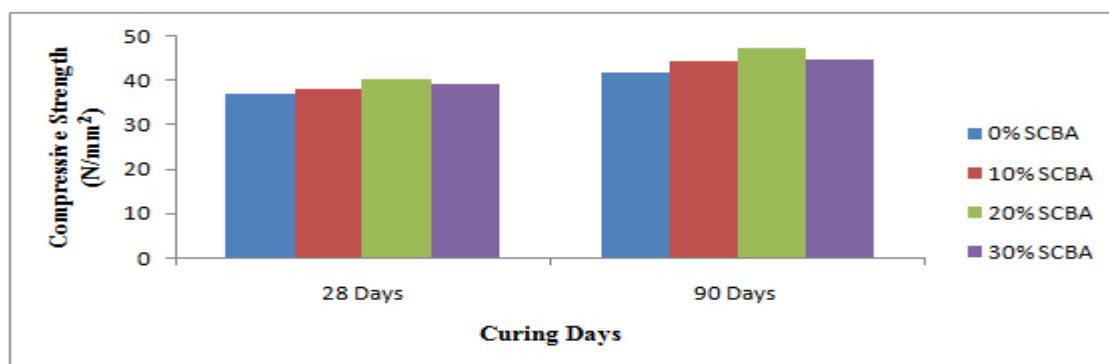


Figure 6: Compressive Strength of SCBA Concrete at different Ages of Curing

Srinivasan and Sathiya (2010)

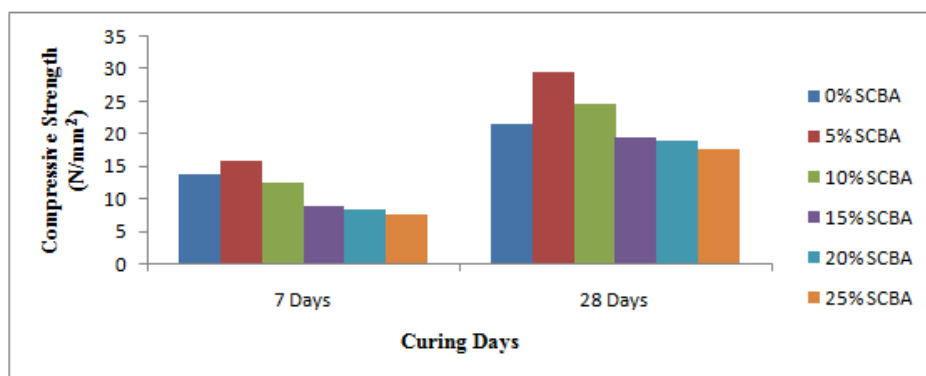


Figure 7: Compressive Strength of SCBA Concrete at different Ages of Curing

GROUNDNUT SHELL ASH (GSA)

The ground nut shells are the by-product of groundnut processing and considered an agricultural waste from groundnut milling process. The shell has to be burnt at a temperature of 550°C-600°C to produce Ground Shell Ash.

Properties of GSA

GSA contains small amount of silicon dioxide, calcium oxide, aluminum and ferrous oxide. The chemical analysis of GSA from different researchers is given in Table 5.

Workability and Strength Characteristics of GSA Concrete

Buari et al. (2013) evaluated the potentials of GSA as partial replacement for cement in concrete. The compressive strength and splitting tensile strength were determined in their experiment. The results of experiment demonstrated that compressive strengths of the control (0%) and those of other percentage combinations of GSA increased with curing age but decreased with increased GSA percentage. So they concluded that the GSA concrete of 10% replacement performed better in comparison to the acceptable standard and more suitable for mass concrete production. The compressive strength behavior at different curing ages with various percentage of GSA is shown in Figure 8.

Table 5: Chemical Composition of GSA

| Chemical Composition | Olutoge and Adeleke (2013) | Mahmoud and Nwakaire (2012) | Wazumtu and Ogork (2015) |
|--------------------------------|----------------------------|-----------------------------|--------------------------|
| SiO ₂ | 16.21 | 26.96 | 22.00 |
| Al ₂ O ₃ | 5.93 | 5.82 | 2.00 |
| Fe ₂ O ₃ | 1.80 | 0.50 | 5.04 |
| MgO | 6.74 | 5.60 | 3.00 |
| CaO | 8.69 | 9.50 | 24.10 |
| LOI | 4.80 | 22.00 | 4.36 |

Nwofer and Sule (2012) studied the use of considerable volume of GSA as the partial replacement for cement in concrete production. They observed the compressive strength behavior of concrete by replacing cement with GSA up to 40% with 10% increment for each mixture. They found that a percentage replacement level greater than 10% may not be adequate for quality concrete work.

Okigbo (2013) investigated the effect of GSA on compressive strength and workability of concrete. He was performed his experiment at two water cement (w/c) ratio i.e. 0.35 and 0.60. He found that the workability of concrete was increased as the percentage replacement of GSA increased with cement. The slump of concrete was increased from 12 to 20.2 when cement replaced with GSA up to 20%. He also examined that the compressive strength of concrete decreased with increase in GSA content at 0.60 w/c ratio while at 0.35 w/c ratio the strength was increased as compared to control mixture. The workability characteristic of GSA concrete is illustrated by Figure 9.

Buari et al. (2013)

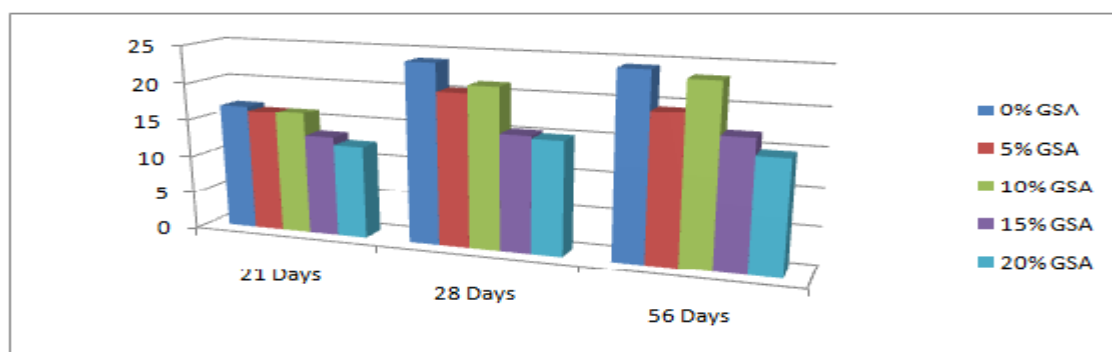


Figure 8: Compressive Strength of GSA Concrete at Different ages of Curing

Wazumtu and Ogork (2015) assessed the effect of GSA as admixture on cement paste and concrete. The GSA was obtained by controlled burning of groundnut shell in an incinerator to a temperature of 600°C and after cooling was sieved through a 75µm sieve and characterized. Six mixtures were prepared with different percentage addition of GSA (0%, 1%, 2%, 3%, 4%, 5%, and 6%). They found from their experiment that the slump of concrete decreased with increase in addition of GSA content. They also observed that compressive strength of concrete increased with curing age and also increased with addition of GSA but up to 4% replacement. Further increase in addition of GSA showed a decrease in compressive strength of the concrete.

Okigbo (2013)

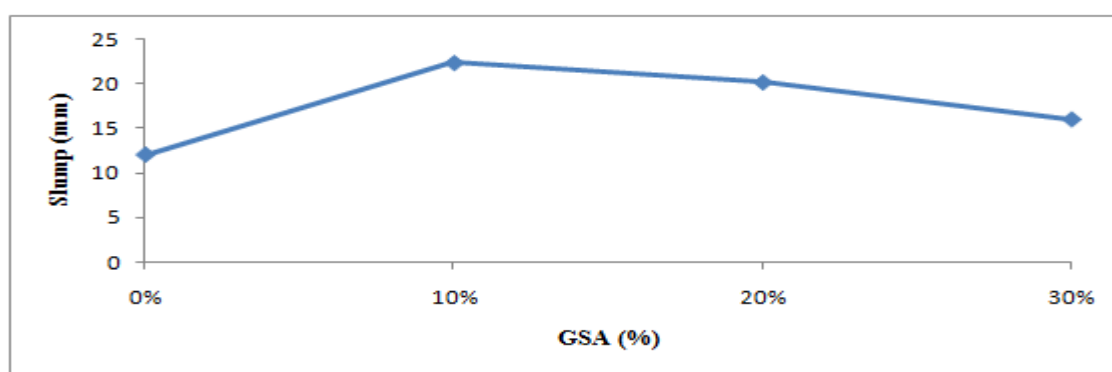


Figure 9: Slump Value of RHA Concrete Mixture

COCONUT SHELL

Coconut shell is an abundantly available agricultural waste from local coconut industries. It represents more than 60% of the domestic waste volume which causes serious disposal problem for local environment. Mostly, the farmers

dispose these shells by burning or allowing rot into the field. As we know that the burning of shells causes air pollution, soil erosion and reduce the soil biological activities while allowing shells to rot in soil can cause phytosanitary problem to coconut plantation. To mitigate these problems, it becomes necessary to find another way of disposal which is more environments safe and friendly. So, using the coconut shells as aggregates in concrete can be a solution to these problems.

Properties of Coconut Shell

Shells have good durability characteristics, high toughness and excellent abrasion properties. The physical properties of coconut shells are given in Table 6.

Table 6: Physical Properties of Coconut Shells

| Sr. No | Physical Properties | Ahlawat and Kalurkar (2014) | Rao et al. (2015) |
|--------|-----------------------------------|-----------------------------|-------------------|
| 1 | Specific gravity | 1.33 | 1.33 |
| 2 | Water absorption (%) | 2.4 | 4.5 |
| 3 | Bulk density (kg/m ³) | 800 | - |
| 4 | Shell thickness | (2-7)mm | - |

Workability and Strength Characteristics of Concrete by using Coconut Shells as Coarse Aggregates

Ahlawat and Kalurkar (2014) studied the effect of coconut shells as coarse aggregates replacement on strength behavior of concrete. They found that the strength of concrete decreases as the percentage replacement of coconuts shells increases but the reduction was very marginal. So, they concluded that the coarse aggregates could be replaced with coconut shells.

Osei (2014) demonstrated that the use of coconuts shells as partial replacement of aggregates can encouraged the environmental protection and construction cost reduction. He replaced coarse aggregates with shells up to 100% and observed the compressive strength and density of each concrete mixture. He found that coconuts shells reduced the strength and density of concrete but the 18.5% replacement of coarse aggregates with coconut shells can be used to produce structural concrete.

Reddy et al (2014) examined the properties of coconut shell aggregate concrete. They analyzed the workability and strength characteristics of concrete by replacing aggregates with coconut shells and found that workability of concrete decreased as the percentage content of coconut shell increased. They also observed that the compressive and flexural strength of concrete decreased when coarse aggregates were replaced with coconut shells.

Kambli and Mathapati (2014) observed that coconut shells have high potential as lightweight aggregate in concrete. They investigated the feasibility of the combination of coconut shell as coarse aggregate in concrete by determining its compressive strength and durability and concluded that the coconut shells were more suitable as low strength-giving lightweight aggregate when used to replace common coarse aggregate in concrete production

Kakade and Dhawale (2015) analyzed an investigation on the behavior of concrete specimens produce from coconut shell aggregate. They found that the concrete gave the strength of 21.31 N/mm² at 25% replacement of aggregates with coconut shell which satisfied the requirement for structural lightweight.

CONCLUSIONS

The published research literature shows that the strength development pattern of agrowaste concrete is much similar to that of conventional concrete but there is loss in strength due to inclusion of some agrowaste such as groundnut ash and coconut shell. From the review of published research, it is concluded that:-

- Use of agrowaste in concrete will help in waste and pollution reduction.
- Its use in concrete construction will help in relieving the potential issue of dwindling natural resources.
- Its use will also help to reduce the material cost in construction.

Till date only fly ash (industrial waste) has been used as cement replacement in concrete while the use of agrowaste is very rare. Therefore, it becomes necessary for sustainable and clean environment that the agrowaste would be used in low costing housing, in rural areas and places where agrowaste is abundant.

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